

SOILS CLASSIFICATION

Malcolm Ulrich
Engineering Geologist

Clay Size		Silt Size			Fine Sand		Medium Sand		Coarse Sand	Fine Gravel		Coarse Gravel		Cobbles ²		Unified Soil Classification ASTM D2487 (FAA, US-DOD, USBR, TVA)		
Fines (Clay and Silt) ¹					Fine Sand		Medium Sand		Coarse Sand		Gravel				Boulders		AASHTO Soil Classification AASHTO N-145	
Silt Clay (combined silt and clay)					Fine Sand		Coarse Sand		Gravel				Boulders				AASHTO Soil Classification AASHTO N-145	
Colloids ³	Clay	Silt			Fine Sand		Coarse Sand		Fine Gravel		Medium Gravel		Coarse Gravel		Boulders		AASHTO Soil-Aggregate AASHTO N-146	
Clay		Silt			Fine Sand		Coarse Sand		Fine Gravel		Coarse Gravel				U.S. Dept. of Agriculture Soil Classification			
Clay Size		Silt Size			Fine Sand		Coarse Sand		Gravel				Prior FAA Soil Classification (Unified system is in current use)					
Clay and Silt					Fine Sand		Coarse Sand		Gravel									
Clay	Fine Silt	Medium Silt	Coarse Silt	Fine Sand	Medium Sand	Coarse Sand	Fine Gravel	Medium Gravel	Coarse Gravel		British Standard BS1377							
<div><div>Sieve Size</div><div><div>.001</div><div>.002</div><div>.005</div><div>.006</div><div>.020</div><div>.050</div><div>.075</div><div>.25</div><div>.60</div><div>2.0</div><div>4</div><div>6</div><div>10</div><div>20</div><div>60</div><div>100</div></div><div>Particle Size, mm</div></div>																		

¹Clay: $PI \geq 4$ and plot of PI vs. LL falls above "A" line in Table 4.

Silt: $PI < 4$ or plot of PI vs. LL falls below "A" line in Table 4.

²Boulders are particles retained on a 12-in. square opening sieve.

³Colloids are part of the clay fraction.

Boulder	Cobble	Gravel		Sand		Silt	Clay
		Coarse	Fine	Coarse	Fine		
SIEVE SIZES							
3"	3"	1"	#4	#4	#200		
PARTICLE SIZE - mm							
75	75	25	4.75	4.75	0.075		

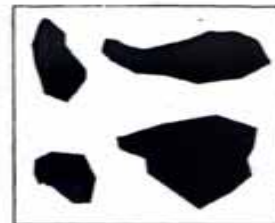
PARTICLE SIZE LIMITS



Rounded



Subrounded



Angular

IDENTIFICATION PROCEDURE CHART

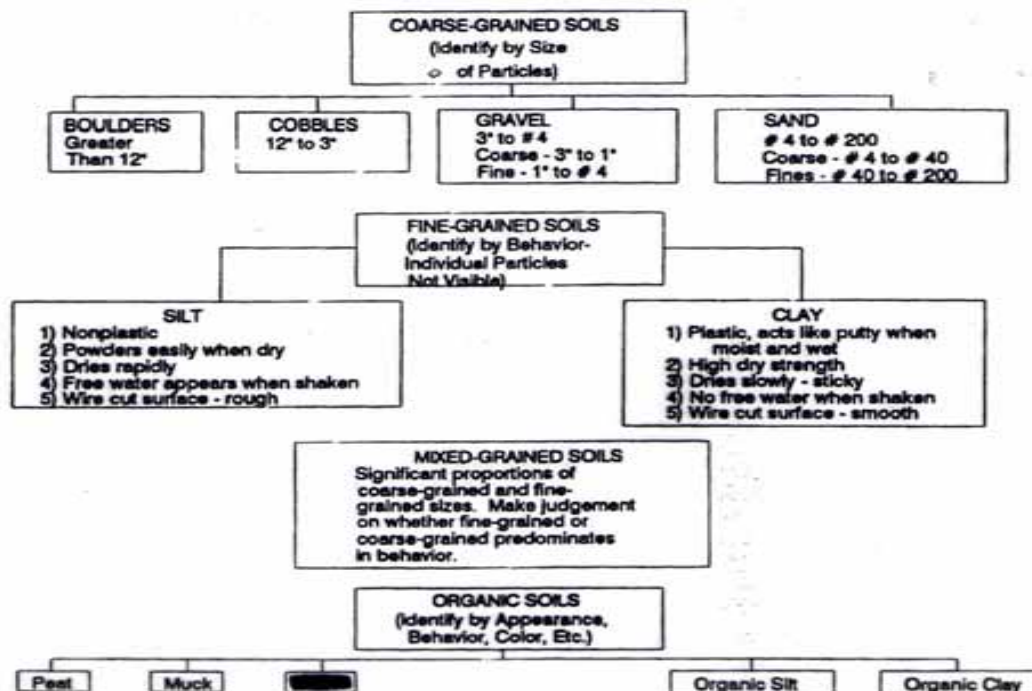
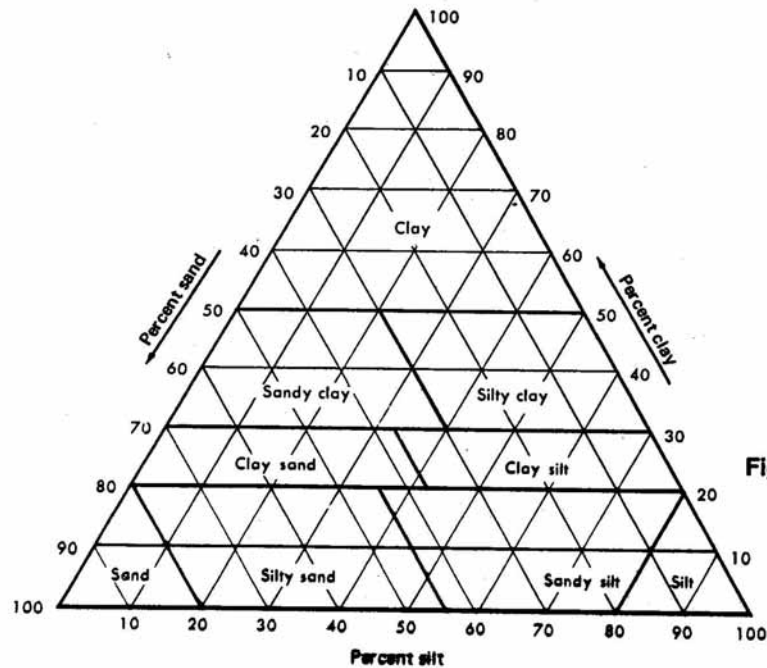
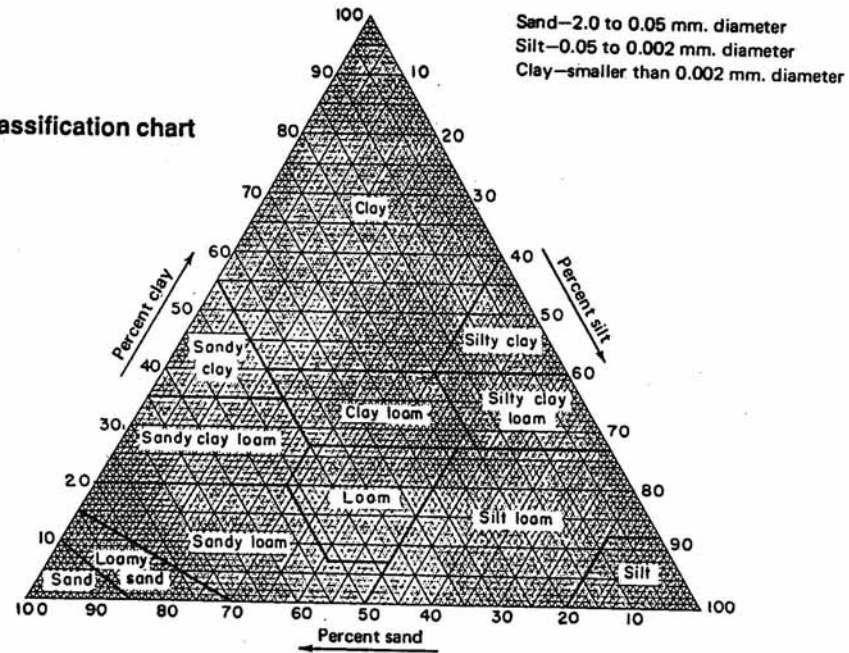


TABLE 2: SILT AND CLAY CHARACTERISTICS

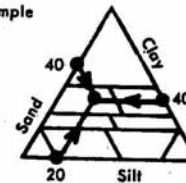
(After Ref.24)

CHARACTERISTICS	SILTS	CLAYS
DILATANCY (reaction to shaking. Movement of water in voids). <ul style="list-style-type: none"> • None • Slow • Rapid 	Rapid reaction. Water appears on the surface to give a livery appearance when shaken. Squeezing the soil causes water to disappear rapidly.	Sluggish or no reaction. Surface of the samples remain lustrous. Little or no water appears when hand is shaken. Sample remains lustrous during squeezing.
DRY STRENGTH (Cohesiveness in dry state). <ul style="list-style-type: none"> • None • Low • Medium • High • Very High 	None to low. Even oven-dry strength is low. Powder easily rubs off surface of the sample. Little or no cohesive strength will crumble and slake readily.	High to very high. Exceptionally high if oven-dry. Powder will not rub off the surface. Crumbles with difficulty. Slakes slowly.
TOUGHNESS (Plasticity in moist state). <ul style="list-style-type: none"> • Low • Medium • High 	Plastic thread has little strength. Dries quickly. Crumbles easily as it dries below plastic range. Seldom can be rolled to 1/8" thread without cracking.	Plastic thread has high strength. Dries slowly. Usually stiff and tough as it dries below plastic range. Can easily be rolled to 1/8" thread without cracking.
DISPERSION (Settlement in water).	Settles out of suspension in 15 to 60 minutes. (Sands settle in 30 to 60 seconds).	Settles in several hours or days, unless it flocculates (rapidly precipitates out in small clumps).
VISUAL INSPECTION AND FEEL	Only coarsest individual silt grains are visible to the naked eye. Feels slightly gritty when rubbed in fingers. Dries quickly and dusts off easily.	Individual grains cannot be observed by the naked eye. Feels smooth and greasy when rubbed in fingers. Dries slowly and does not dust off, must be scraped off.
BITE TEST (Caution: Eating contaminated soil may be hazardous to your health)	Gritty feeling between the teeth, does not stick to the teeth.	No gritty feeling between the teeth; tends to stick to the teeth.

Fig. 2. USDA textural classification chart



Example



Silt—20 percent
Sand—40 percent
Clay—40 percent

Therefore the sample is a sandy clay.

Fig. 3. FAA textural classification chart

Table 1—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 0.075 mm)			Silt-Clay Materials (More Than 35 Percent Passing 0.075 mm)			
Group Classification	A-1	A-3 ^a	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max	51 min	—	—	—	—	—
0.075 mm (No. 200)	25 max	10 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—			40 max	41 min	40 max	41 min
Plasticity index	6 max	NP	^b	10 max	10 max	11 min	11 min
General rating as subgrade	Excellent to Good			Fair to Poor			

^a The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.

^b See Table 2 for values.

Table 2—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 0.075 mm)							Silt-Clay Materials (More Than 35 Percent Passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve analysis, percent passing:											
2.00 mm (No. 10)	50 max	—	—	—	—	—	—	—	—	—	—
0.425 mm (No. 40)	30 max	50 max	51 min	—	—	—	—	—	—	—	—
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid limit	—		—	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

* Plasticity index of A-7-5 subgroup is equal to or less than 1.0; A-7-6 is equal to or less than 0.5.

^a Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30. (See Figure 2.)

6.1.

The group index is calculated from the following formula:

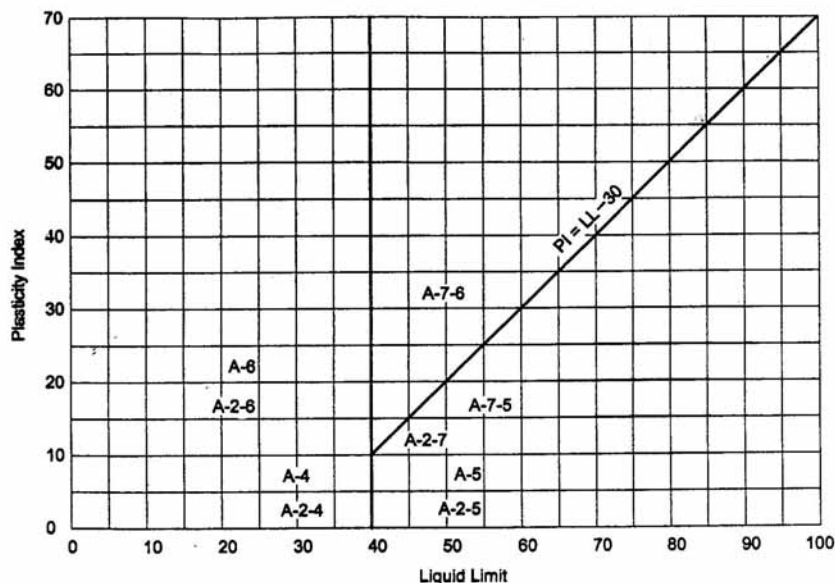
$$\text{Group index} = (F - 35) [0.2 + 0.005 (LL - 40)] + 0.01 (F - 15) (PI - 10)$$

where:

F = percentage passing 0.075-mm (No. 200) sieve, expressed as a whole number. This percentage is based only on the material passing the 75-mm (3-in.) sieve.

LL = liquid limit, and

PI = plasticity index.



Note: A-2 Soils contain less than 35 percent finer than the 0.075-mm (No. 200) Sieve.

Figure 2—Liquid Limit and Plasticity Index Ranges for Silt-Clay Materials

7.

BASIS FOR GROUP INDEX FORMULA

7.1.

The empirical group index formula devised for approximately within-group evaluation of the "clayey granular materials" and the "silt-clay materials" is based on the following assumptions:



LAB SAMPLE NO.	W-03-0498-AG	W-03-0499-AG	W-03-0500-AG	W-03-0501-AG	W-03-0502-AG	W-03-0503-AG	W-03-0504-AG	W-03-0505-AG
FIELD SAMPLE NO	TP-3B	TP-4A	TP-4B	TP-5A	TP-5B	TP-6	TP-7A	TP-7B
SAMPLE OF:	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S	Silty Gravel/S
SOURCE NO:	49DNP0006	49DNP0006	49DNP0006	49DNP0006	49DNP0006	49DNP0006	49DNP0006	49DNP0006
DEPTH:	2-4.5m	0.5-1.5m	1.5-2.5m	0.5-3m	2-4m	0-2.2m	1-4m	2-4m
BORING NO:	TP-3	TP-4	TP-4	TP-5	TP-5	TP-6	TP-7	TP-7

GRAD. PCT. PASS

100mm						100.0		
75mm	100.0	100.0		100.0	100.0	95.4	100.0	100.0
50mm	95.4	98.2	100.0	97.6	94.2	93.5	99.2	97.0
37.5mm	92.9	94.6		97.4	91.0	90.9	97.3	95.3
25.0mm	86.3	89.4	88.5	91.5	82.3	85.6	93.2	88.8
19.0mm	80.4	85.7	83.7	85.9	76.2	81.0	85.1	83.2
12.5mm	71.4	80.3	75.1	76.2	66.9	73.6	73.9	73.6
9.5mm	65.0	75.1	68.5	69.5	60.7	67.9	65.5	66.7
4.75mm	51.6	62.3	53.8	54.5	48.3	55.5	50.6	51.7
2.00mm	40.3	51.2	41.9	42.5	34.9	44.1	37.7	37.9
425µm	21.4	30.6	24.0	22.5	12.4	26.6	18.6	17.1
150µm	11.7	20.2	13.0	14.4	6.0	17.8	9.9	8.5
75µm	8.6	15.4	9.8	11.2	4.3	14.2	7.2	6.2
20µm								

AASHTO DESC
AASHTO CLASS
UNIFIED CLASS

SI-SA-GRAVEL
A-1-a(0)
GW-GM;
Well-graded
gravel with
silt and
sand

SI-SA-GRAVEL
A-1-a(0)
GW-GM;
Well-graded
gravel with
silt and
sand

SI-SA-GRAVEL
A-1-a(0)
GP; Poorly
graded
gravel with
sand

SI-SA-GRAVEL
A-1-a(0)
GW-GM;
Well-graded
gravel with
silt and
sand

T89 LL NP
T89 PI NP

NP
NP

NP
NP

NP
NP

SE REF AS RCVD 54

45 62

58

DUR. COARSE
DUR. FINE 52

67 67
48 54

55

L.A. ABRASION
B 23.0

24.0 25.0

23.0

SOUNDNESS % LOSS
TO MID SPECS 3.89

2.87 3.38

2.68

DMSO WEATHERING
TO MID SPECS 3.70

5.05 4.44

APP. SG. COARSE 2.683
APP. SG. FINE 2.668
APP. SG. SOIL

2.661 2.684
2.668 2.667

2.687
2.670

NAT. % MOIST. a

pH VALUE

TEST PIT SAMPLES

June 2003

Source 49-DNP-006

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^A				Soil Classification		
				Group Symbol	Group Name ^B	
COARSE-GRAINED SOILS More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines ^C	$Cu \geq 4$ and $1 \leq Cc \leq 3^E$	GW	Well-graded gravel	
			$Cu < 4$ and/or $1 > Cc > 3^E$	GP	Poorly graded gravel ^F	
		Gravels with Fines More than 12 % fines ^C	Fines classify as ML or MH	GM	Silty gravel ^{F,G,H}	
			Fines classify as CL or CH	GC	Clayey gravel ^{F,G,H}	
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines ^D	$Cu \geq 6$ and $1 \leq Cc \leq 3^E$	SW	Well-graded sand ^I	
			$Cu < 6$ and/or $1 > Cc > 3^E$	SP	Poorly graded sand ^I	
		Sands with Fines More than 12 % fines ^D	Fines classify as ML or MH	SM	Silty sand ^{G,H,I}	
			Fines classify as CL or CH	SC	Clayey sand ^{G,H,I}	
	FINE-GRAINED SOILS 50 % or more passes the No. 200 sieve	Silt and Clays Liquid limit less than 50	inorganic	$PI > 7$ and plots on or above "A" line ^J	CL	Lean clay ^{K,L,M}
				$PI < 4$ or plots below "A" line ^J	ML	Silt ^{K,L,M}
organic			Liquid limit – oven dried Liquid limit – not dried < 0.75	OL	Organic clay ^{K,L,M,N} Organic silt ^{K,L,M,O}	
Silt and Clays Liquid limit 50 or more		inorganic	PI plots on or above "A" line	CH	Fat clay ^{K,L,M}	
			PI plots below "A" line	MH	Elastic silt ^{K,L,M}	
		organic	Liquid limit – oven dried Liquid limit – not dried < 0.75	OH	Organic clay ^{K,L,M,P} Organic silt ^{K,L,M,Q}	
HIGHLY ORGANIC SOILS		Primarily organic matter, dark in color, and organic odor		PT	Peat	

^A Based on the material passing the 3-in. (75-mm) sieve.

^B If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

^C Gravels with 5 to 12 % fines require dual symbols:

GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

^D Sands with 5 to 12 % fines require dual symbols:

SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

$$Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

^E If soil contains ≥ 15 % sand, add "with sand" to group name.

^F If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

^G If fines are organic, add "with organic fines" to group name.

^H If soil contains ≥ 15 % gravel, add "with gravel" to group name.

^I If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

^K If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

^L If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.

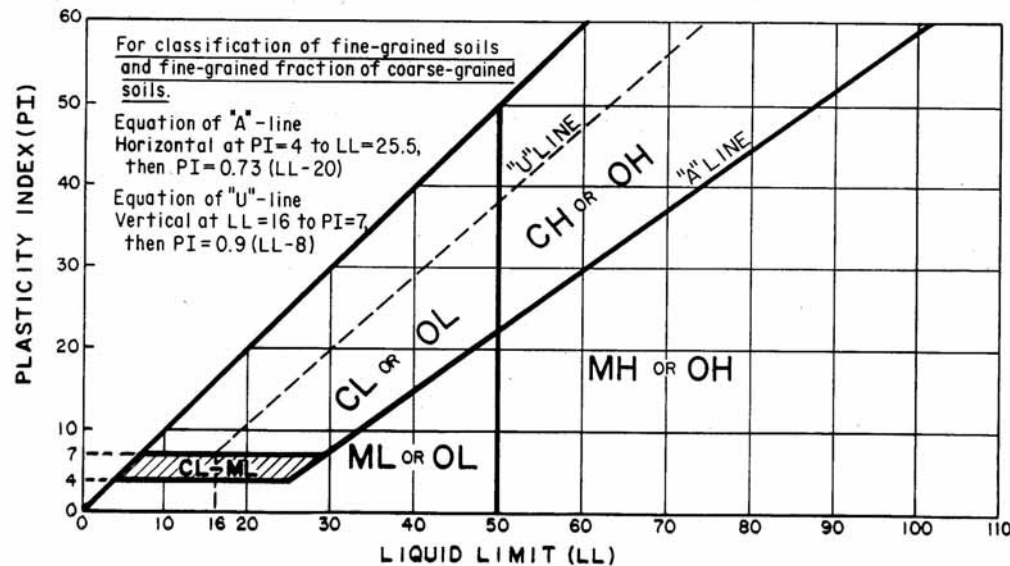
^M If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.

^N $PI \geq 4$ and plots on or above "A" line.

^O $PI < 4$ or plots below "A" line.

^P PI plots on or above "A" line.

^Q PI plots below "A" line.





- D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75- μ m) Sieve⁴
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock⁴
- D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants⁴
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)⁴
- D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction⁵
- D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)⁴
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils⁴
- D 4427 Classification of Peat Samples by Laboratory Testing⁴
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁶

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75- μ m) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the “A” line.

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

Coarse—passes 3-in. (75-mm) sieve and retained on $\frac{3}{4}$ -in. (19-mm) sieve, and

Fine—passes $\frac{3}{4}$ -in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75- μ m) U.S. standard sieve with the following subdivisions:

Coarse—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

Medium—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425- μ m) sieve, and

Fine—passes No. 40 (425- μ m) sieve and retained on No. 200 (75- μ m) sieve.

3.1.7 *silt*—soil passing a No. 200 (75- μ m) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the “A” line.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature, C_c* —the ratio $(D_{30})^2 / (D_{10} \times D_{60})$, where D_{60} , D_{30} , and D_{10} are the particle sizes corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity, C_u* —the ratio D_{60}/D_{10} , where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

⁵ Annual Book of ASTM Standards, Vol 04.09.

⁶ Annual Book of ASTM Standards, Vol 14.02.





Project Name: Denali Rd. Evaluation, Ph.II/Porcupine Forest		Sample No: TP5a	
Project Number: AK PRA DENA ES 3		Sampled By: M. Ulrich	
Acct. No.: 1517020700003	510.G0.F170.02	Date Sampled: 8/31/2007	
Submitted By: M. Ulrich		Address: WFLHD, Geotechnical Branch	
Phone: (360)619-7816		610 East Fifth Street	
Fax: (360)619-7845		Vancouver, WA 98661	
Sample of:		Date Received: 11/14/2007	
Quantity Rep:		No. & Containers: Sack + Baggie	
		Dates Tested: 11/14/07-01/28/08	
Owner:		County:	State: AK
Station: 82+070	Milepost:	Offset: 4 Lt	
Boring No./Test Pit: TP5		Depth: 2-5'	

Sieve Analysis

Sieve Size	As Received % Passing
3"	100.0
2"	97.2
1 1/2"	96.0
1"	95.5
3/4"	94.9
1/2"	92.9
3/8"	91.7
#4	89.3
#10	84.0
#40	79.3
#200	69.0
20µm	51.8

Soil Classification (DL145)

AASHTO	A-7-6(26)	SA-GR-CLAY
Unified	CH; Sandy fat clay	

Apparent Specific Gravity (T100) 2.577

Natural Moisture (T265) (Sample dried at 230 °F), % 33.1

Atterberg Limits (T89)

Liquid Limit	60
Plasticity Index	39

R Value Results (WL190)

R Value By Exudation at psi	29
Density At R Value, pcf	101.20
Moisture at R Value, %	23.2

Organic Content by % Loss On Ignition (T267) 4.47

PART I: Description of Soil Phase (Independent of Frozen State)		Classify Soil Phase by the Unified Soil Classification System										
Major Group		Subgroup		Field Identification		Pertinent Properties of Frozen Materials Which Can Be Measured by Physical Tests to Supplement Field Identification		Guide for Construction on Soils Subject to Freezing and Thawing				
								Thaw Characteristics	Criteria			
Part II: Description of Frozen Soil	Segregated ice not visible by eye	N	Poorly bonded or friable	Nf	Identify by visual examination; to determine presence of excess ice, use procedure under note (3) and hand magnifying lens as necessary; for soils not fully saturated estimate degree of ice saturation (medium, low); note presence of crystals or of ice coatings around larger particles	In-place temperature Density and void ratio a. In frozen state b. After thawing in place Water content (total H ₂ O, including ice) a. Average b. Distribution Strength a. Compressive b. Tensile c. Shear d. Adhesion Elastic properties Plastic properties Thermal properties Ice crystal structure (using optical instruments) a. Orientation of axes b. Crystal size c. Crystal shape d. Pattern of arrangement	Usually thaw- stable	The potential intensity of ice segregation in a soil is dependent to a large degree on its void sizes and for pavement design purposes may be expressed as an empirical function of grain size as follows: Most inorganic soils containing 3 percent or more of grains finer than 0.02 mm in diameter by weight are frost-susceptible for pavement design purposes. Gravels, well-graded sands and silty sands, especially those approaching the theoretical maximum density curve, which contain 1.5 to 3 percent finer by weight than 0.02 mm size should be considered as possibly frost-susceptible and should be subjected to a standard laboratory frost susceptibility test to evaluate actual behavior during freezing. Uniform sandy soils may have as high as 10 percent of grains finer than 0.02 mm by weight without being frost-susceptible. However, their tendency to occur interbedded with other soils usually makes it impractical to consider them separately. Soils classed as frost-susceptible under the above pavement design criteria are likely to develop significant ice segregation and frost heave if frozen at normal rates with free water readily available. Soils as frozen will fall into the thaw unstable category. However, they may also be classed as thaw stable if frozen with insufficient water to permit ice segregation. Soils classed as non-frost-susceptible under the above criteria usually occur without significant ice segregation and are usually thaw stable for pavement applications. However, the criteria are not exact and may be inadequate for some structure applications; exceptions may also result from minor soil variations. In permafrost areas, ice wedges, pockets, veins, or other ice bodies may be found whose mode of origin is different from that described above. Such ice may be the result of long-time surface expansion and contraction phenomena or may be glacial or other ice which has been buried under a protective earth cover.				
			Well bonded	Nb					n			
			Segregated ice visible by eye (ice 25 mm or less thick)	V					Individual ice crystals or inclusions	Vx	For ice phase, record the following as applicable: Location Size Orientation Shape Thickness Pattern of Length arrangement Spacing Hardness Structure Color } per part III below	Usually thaw- unstable
									Ice coatings on particles	Vc		
Random or irregularly oriented ice formations	Vr											
		Stratified or distinctly oriented ice formations	Vs	Estimate volume of visible segregated ice present as percent of total sample volume								
Part III: Description of Substantial Ice State	Ice greater than 25 mm thick	ICE	Ice with soil inclusions	ICE + soil type	Designate material as ice and use descriptive terms as follows, usually one item from each group, as applicable: Hardness: hard, soft (of mass, not of individual crystals) Structure: clear, cloudy, porous, cantered, granular, stratified Color: colorless, gray, blue Admixtures: contains few thin silt inclusions	Same as part II above, as applicable, with special emphasis on ice crystal structure						
			Ice without soil inclusions	ICE								
DEFINITIONS										NOTES		
<p>Ice coatings on particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.</p> <p>Ice crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in combination with other ice formations.</p> <p>Clear ice is transparent and contains only a moderate number of air bubbles.</p> <p>Cloudy ice is translucent but essentially sound and nonporous.</p> <p>Porous ice contains numerous voids, usually interconnected and resulting (1) from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water or (2) from the freezing of saturated snow. Though porous, the mass retains its structural unity.</p> <p>Cantered ice is ice which has rotted or otherwise formed into long columnar crystals, very loosely bonded together.</p> <p>Ice lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.</p> <p>Ice segregation is the growth of ice as distinct lenses, layers, veins, and masses in soils, commonly but not always oriented normal to direction of heat loss.</p> <p>Well bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.</p> <p>Poorly bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.</p> <p>Friable denotes a condition in which material is easily broken up under light to moderate pressure.</p> <p>Thaw-stable frozen soils do not, on thawing, show loss of strength below normal long-time thawed values or produce detrimental settlement.</p> <p>Thaw-unstable frozen soils show, on thawing, significant loss of strength below normal long-time thawed values and/or significant settlement, as a direct result of the melting of the excess ice in the soil.</p>										<p>1. When rock is encountered, standard rock-classification terminology should be used.</p> <p>2. Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. However, the impression to the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.</p> <p>3. When visual methods may be inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt and observing the quantity of supernatant water as a percent of total volume.</p> <p>4. Where special forms of ice, such as hoarfrost, can be distinguished, more explicit description should be given.</p> <p>5. The observer should be careful to avoid being misled by surface scratches or frost coating on the ice.</p> <p>6. The letter symbols shown are to be affixed to the Unified Soil Classification letter designations or may be used in conjunction with graphic symbols, in exploration logs or geologic profiles. For example, a lean clay with essentially horizontal ice lenses:</p> <div><div>CL - Vs</div>or<div>Vs</div></div> <p>The descriptive name of the frozen soil type and a complete description of the frozen material are the fundamental elements of this classification scheme. Additional descriptive data should be added where necessary. The letter symbols are secondary and are intended only for convenience in preparing graphical presentations. Since it is frequently impractical to describe ice formations in frozen soils by words alone, sketches and photographs should be used where appropriate to supplement descriptions.</p>		

LOCATION:	MP 0.5	MP 1.0 west bo	MP 1.5 west bo	MP 2.5 west bo	MP 3.5 east bo	MP 4.0 west bo	MP 4.5 west bo
DEPTH	355-1750 m	610-1750 m	660-1740 m	355-1730 m	785-1730 m	340-1870 m	280-1870 m
XX							
GRAD. PCT. PASS							
2"	100.0		100.0		100.0		
1 1/2"	99.1	100.0	98.1		98.7		
1"	98.1	89.4	97.6	100.0	98.4	100.0	
3/4"	96.3	88.6	97.0	99.8	97.9	99.7	100.0
1/2"	92.1	88.1	96.5	99.7	97.6	99.5	99.6
3/8"	89.5	75.3	94.8	99.5	97.4	99.4	99.6
#4	83.5	75.3	93.3	98.2	96.9	99.2	98.5
#10	81.5	74.4	92.1	96.8	96.3	99.0	98.3
#40	77.5	62.5	74.7	84.2	89.3	89.2	92.9
#200	72.5	37.7	67.2	77.4	77.5	76.9	81.3
0.020mm	61.7	29.0	57.9	67.1	63.2	59.3	64.4
0.010mm	54.3	22.3	50.3	60.4	54.2	50.3	53.9
0.005mm	44.5	18.0	42.3	53.6	45.0	40.9	44.7
0.002mm	34.2	13.0	29.8	43.4	34.4	31.3	34.3
PCT GRAVEL	18.5	25.6	7.9	3.2	3.7	1.0	1.7
PCT COARSE SAND	4.0	12.0	17.4	12.5	7.0	9.8	5.4
PCT FINE SAND	5.0	24.8	7.5	6.9	11.9	12.3	11.6
PCT SILT	38.3	24.7	37.3	34.0	43.1	45.5	47.0
PCT CLAY	34.2	13.0	29.8	43.4	34.4	31.3	34.3
AASHTO DESC	SA-GR-CLAY	GR-SA-SILT	GR-SA-SILT	GR-SA-CLAY	GR-SA-CLAY	GR-SA-SILT	GR-SA-SILT
AASHTO CLASS	A-7-5(20)	A-4(0)	A-5(10)	A-7-5(15)	A-7-5(16)	A-4(0)	A-4(0)
UNIFIED CLASS	MH; Elastic silt with gravel	SM; Silty sand with gravel	MH; Sandy elastic silt	MH; Elastic silt with sand	MH; Elastic silt with sand	ML; Silt with sand	ML; Silt with sand
LL.	61	NP	65	61	64	NP	NP
PI.	24	NP	10	13	13	NP	NP
APP. SG. SOIL	2.642	2.642	2.512	2.569	2.599	2.504	2.506
R.V. BY EXUD.							
@ 300 P.S.I.	39	47	46	43	33	35	38
R-V BY EXPAN.	37	50	46	N/Exp	37	49	42
R-V DENSITY	91.4	82.7	65.0	75.3	73.8	69.6	70.6
R-V MOISTURE	29.9	33.0	55.7	40.0	45.7	46.4	45.4

SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE GRAINED SOILS More Than 50% Retained on No. 200 Sieve	GRAVEL More Than 50% of Coarse Fraction Retained on No. 4 Sieve	CLEAN GRAVEL	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVEL WITH FINES	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND More Than 50% of Coarse Fraction Passes No. 4 Sieve	CLEAN SAND	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS More Than 50% Passes No. 200 Sieve	SILT AND CLAY Liquid Limit Less Than 50	INORGANIC	ML	SILT
			CL	CLAY
	SILT AND CLAY Liquid Limit 50 or More	ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
			INORGANIC	MH
		ORGANIC		CH
			OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT

NOTES:

- Field classification is based on visual examination of soil in general accordance with ASTM D2488-90.
- Soil classification using laboratory tests is in general accordance with ASTM D2487-90.
- Descriptions of soil density or consistency are based on interpretation of blow count data, visual appearance of soils, and/or test data.

SOIL MOISTURE MODIFIERS:

- Dry - Absence of moisture, dusty, dry to the touch
- Moist - Damp, but no visible water
- Wet - Visible free water or saturated, usually soil is obtained from below water table

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		GM	SILTY GRAVELS, GRAVEL - SAND MIXTURES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SP	POORLY-GRADED SANDS, GRAVELLY SAND
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
				ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
				MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
HIGHLY ORGANIC SOILS				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

Sampler Symbol Descriptions

- 2.4-inch I.D. split barrel
- Standard Penetration Test (SPT)
- Shelby tube
- Piston
- Direct-Push
- Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS		TYPICAL DESCRIPTIONS
GRAPH	LETTER	
	CC	Cement Concrete
	AC	Asphalt Concrete
	CR	Crushed Rock/Quarry Spalls
	TS	Topsoil/Forest Duff/Sod

- Measured groundwater level in exploration, well, or piezometer
- Groundwater observed at time of exploration
- Perched water observed at time of exploration
- Measured free product in well or piezometer

Stratigraphic Contact

- Distinct contact between soil strata or geologic units
- Gradual change between soil strata or geologic units
- Approximate location of soil strata change within a geologic soil unit

Laboratory / Field Tests

- %F Percent fines
- AL Atterberg limits
- CA Chemical analysis
- CP Laboratory compaction test
- CS Consolidation test
- DS Direct shear
- HA Hydrometer analysis
- MC Moisture content
- MD Moisture content and dry density
- OC Organic content
- PM Permeability or hydraulic conductivity
- PP Pocket penetrometer
- SA Sieve analysis
- TX Triaxial compression
- UC Unconfined compression
- VS Vane shear

Sheen Classification

- NS No Visible Sheen
- SS Slight Sheen
- MS Moderate Sheen
- HS Heavy Sheen
- NT Not Tested

KEY TO EXPLORATION LOGS



UNIFIED SOIL CLASSIFICATION SYSTEM

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
Clean Gravels (Less than 5% fines)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty (of) clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LABORATORY CLASSIFICATION CRITERIA

GW $C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3

GP Not meeting all gradation requirements for GW

GM Atterberg limits below "A" line or P.I. less than 4

GC Atterberg limits above "A" line with P.I. greater than 7

Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols

SW $C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3

SP Not meeting all gradation requirements for GW

SM Atterberg limits below "A" line or P.I. less than 4

SC Atterberg limits above "A" line with P.I. greater than 7

Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent GW, GP, SW, SP
More than 12 percent GM, GC, SM, SC
5 to 12 percent Borderline cases requiring dual symbols

PLASTICITY CHART

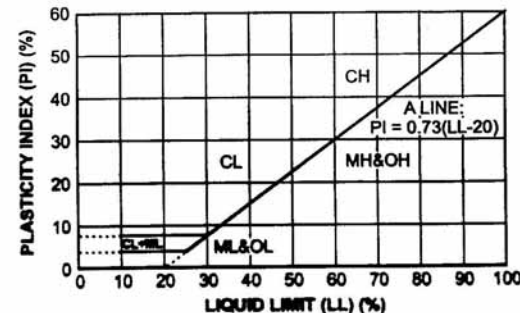


Table B-3. Characteristics of soil groups pertaining to roads and airfields

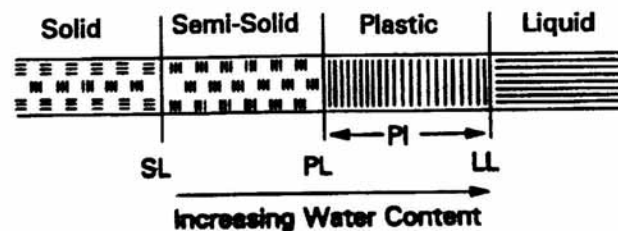
Major Divisions (1) (2)		Letter (3)	Symbols		Name (6)	Value As Subgrade When not Subject to Frost Action (7)	Value As Subbase When not Subject to Frost Action (8)
			Hatching (4)	Color (5)			
Coarse-Grained Soils	Gravel and Gravelly Soils	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Good
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Good
		GC			Clayey gravels, gravel-sand-clay mixtures	Good	Fair
	Sand and Sandy Soils	SW		Red	Well-graded sands or gravelly sands, little or no fines	Good	Fair to good
		SP			Poorly graded sands or gravelly sands, little or no fines	Fair to good	Fair
		SM		Yellow	Silty sands, sand-silt mixtures	Fair to good	Fair to good
		SC			Clayey sands, sand-silt mixtures	Fair	Poor to fair
Fine-Grained Soils	Sils and Clays LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor to fair	Not suitable
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Poor to fair	Not suitable
		OL			Organic silts and organic silt-clays of low plasticity	Poor	Not suitable
	Sils and Clays LL ≥ 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable
		CH			Inorganic clays of high plasticity, fat clays	Poor to fair	Not suitable
		OH			Organic clays of medium to high plasticity, organic silts	Poor to very poor	Not suitable
Highly Organic Soils		Pt		Orange	Peat and other highly-organic soils	Not suitable	Not suitable

NOTES: 1. Divisions of the GM and SM groups (column 3) into subdivisions of ^d and ^u are applicable to roads and airfields only. Subdivision is based on the LL and PI; suffix ^d (for example, GM^d) will be used when the LL is 25 or less and the PI is 5 or less; the suffix ^u will be used otherwise.

Plasticity And Atterberg Limits

Another important concept is that of plasticity of soils. During soil identification, a judgment is made that the soil is plastic, or non-plastic but no relative value is assigned. Arbitrary indices have been chosen to define the plasticity of cohesive (clay) soils. These are liquid limit (LL), plastic limit (PL), and plasticity index (PI). These limits quantitatively describe the effect of varying water content on the consistency of fine-grained soils. With increasing water content, fine-grained soils pass consecutively from the solid to semi-solid to plastic to liquid states. These limits and the applicable standard AASHTO test numbers are illustrated graphically below.

<u>Plasticity Characteristics</u>	<u>Symbol</u>	<u>Units</u>	<u>How Obtained</u>	<u>Application</u>
Liquid limit.....	LL	D	Directly from test AASHTO T89	Classification & properties correlation.
Plastic limit.....	PL	D	Directly from test AASHTO T89	Classification.
Plastic index.....	PI	D	LL-PL	Classification & properties correlation.
Shrinkage limit.....	SL	D	Directly from test AASHTO T89	Classification computation of swell.
Shrinkage index.....	SI	D	PL-SL	
Activity.....	Ac	D	$\frac{PI}{\% \text{ "clay size"}}$	Identification of clay mineral.
Liquidity index.....	LI	D	$\frac{W-PL}{PI}$	Estimating degree of preconsolidation.



CHAPTER 2 BASIC SOIL PROPERTIES FOR FOUNDATION DESIGN

The foundation engineer is usually concerned with the construction of some type of engineering structure on or in the earth. For engineering purposes, we shall consider the earth to be made up of rock and soil. Rock is that naturally occurring material composed of mineral particles so firmly bonded together that relatively great effort is required to separate the particles (i.e., blasting or heavy crushing forces). Soil will be defined as naturally occurring mineral particles which are fairly readily separated into relatively small pieces, and in which the mass may contain air, water, or organic materials (derived from decay of vegetation). The mineral particles of the soil mass are formed from decomposition of the rock by weathering (by air, ice, wind, and water) and chemical processes.

MAIN SOIL GROUPS

GRANULAR SOILS-----SANDS AND GRAVELS
FINE-GRAINED SOILS-----SILTS AND CLAYS
ORGANIC SOILS-----PEAT, ORGANIC CLAYS,
AND ORGANIC SILTS

Sieve Size or Number	3"	#4	#10	#200	0.005mm	0.002mm	0.001mm
ASTM	Gravel		Sand		Silt	Clay	Colloid
Unified	Cobbles	Gravel	Sand		Silt or Clay		
AASHTO	Boulders	Gravel	Sand		Silt	Clay	Colloid

The major engineering properties of the main soil groups as related to foundation design are summarized as follows:

Engineering Properties of Soils

Engineering Properties of Granular Soils

1. Excellent foundation material for supporting structures and roads.
2. The best embankment material.
3. The best backfill material for retaining walls.
4. Might settle under vibratory loads or blasts.
5. Dewatering can be difficult due to high permeability.
6. If free draining not frost susceptible.

Engineering Properties of Cohesive Soils

1. Very often possess low shear strength.
2. Plastic and compressible.
3. Loses part of shear strength upon wetting.
4. Loses part of shear strength upon disturbance.
5. Shrinks upon drying and expands upon wetting.
6. Very poor material for backfill.
7. Poor material for embankments.
8. Practically impervious.
9. Clay slopes are prone to landslides.

Engineering Properties of Silt

1. Relatively low shear strength
2. High capillarity and frost susceptibility
3. Relatively low permeability
4. Difficult to compact

Compared to Clay, Silt

5. Has better load sustaining qualities
6. Is less compressible
7. Is more permeable
8. Exhibits less volume change

Engineering Properties of Organic Soils

Any soil containing a sufficient amount of organic matter to influence its engineering properties is called an organic soil. The term organic designates those soils containing an appreciable amount of decayed animal and/or vegetative matter in various states of decomposition.

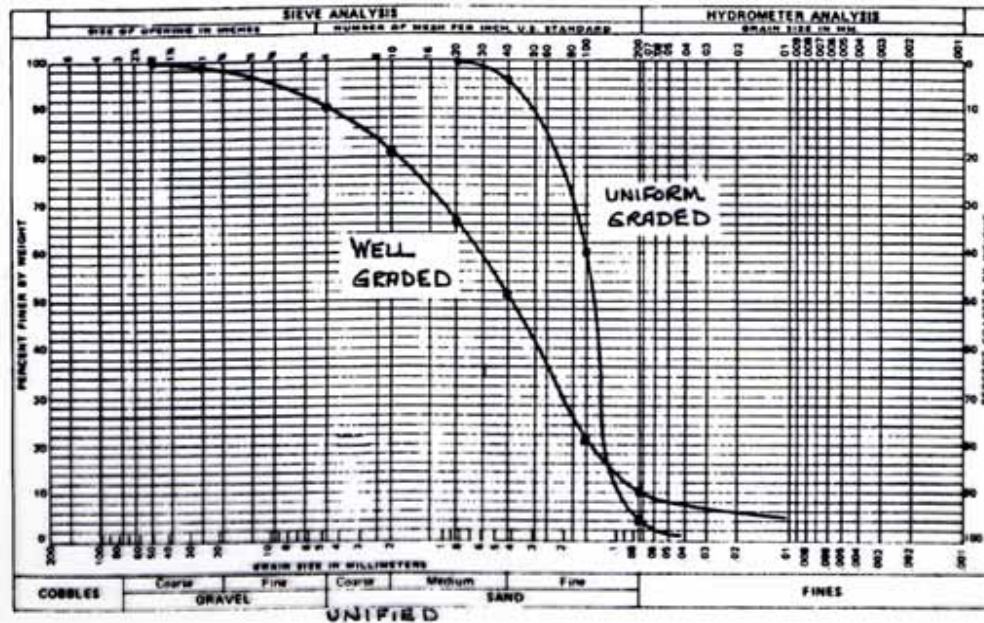
The organic matter is objectionable for three main reasons:

1. Reduces load-carrying capacity of soil.
2. Increases compressibility considerably.
3. Frequently contains toxic gasses that are released during the excavation process.

All organic soils, whether peat, organic clays, organic silts, or even organic sands, should be viewed with suspicion as foundation and construction materials.

Granular Material Properties

Grain size distribution is the single most important element in the design of granular material items. Grain size distribution is determined by sieving a soil sample of known weight through U.S. Standard mesh opening sizes. The percentages of total sample are recorded and plotted on the sheet below. The resulting curves represent the grain size distribution in the soil sample.



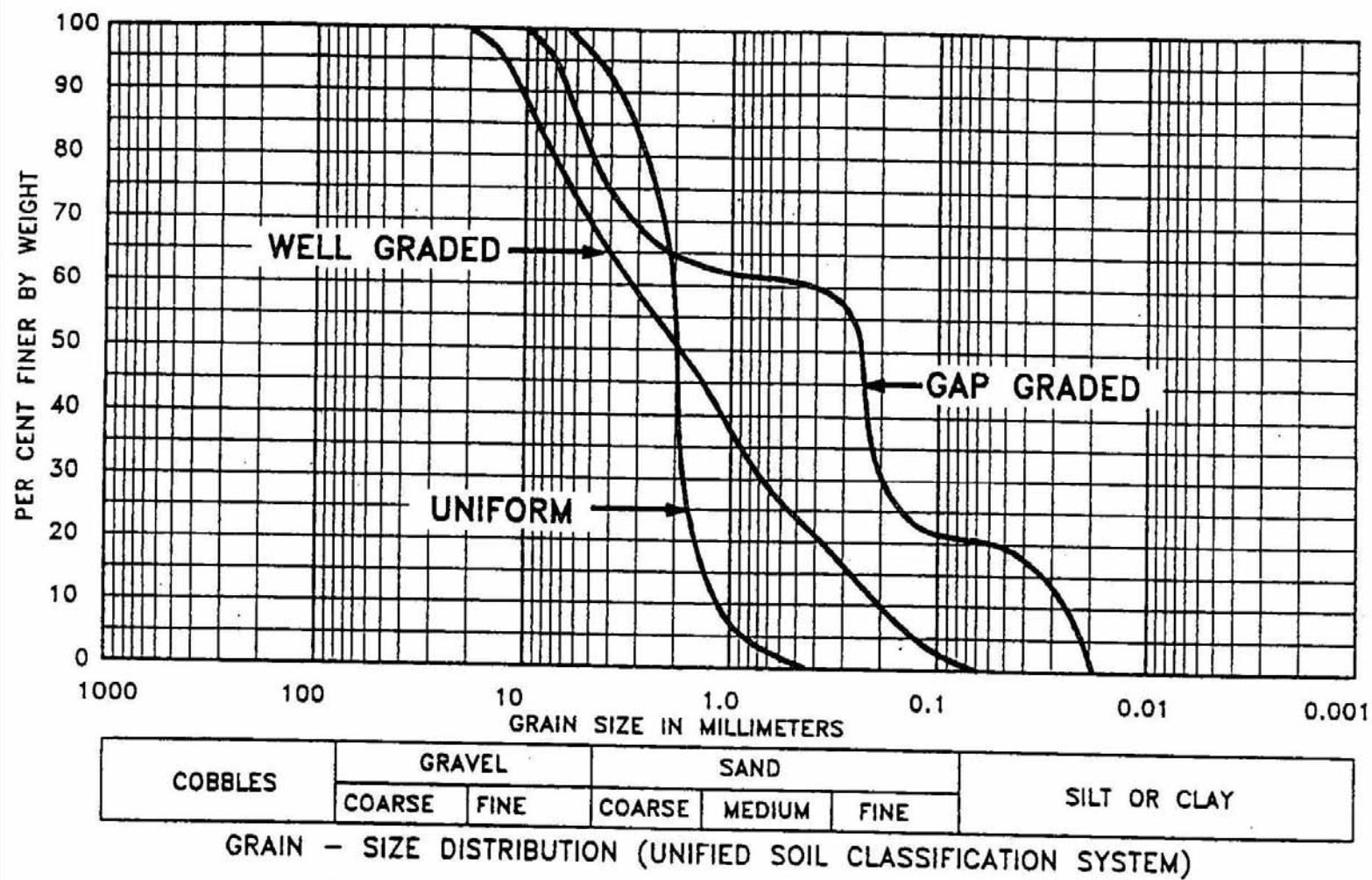
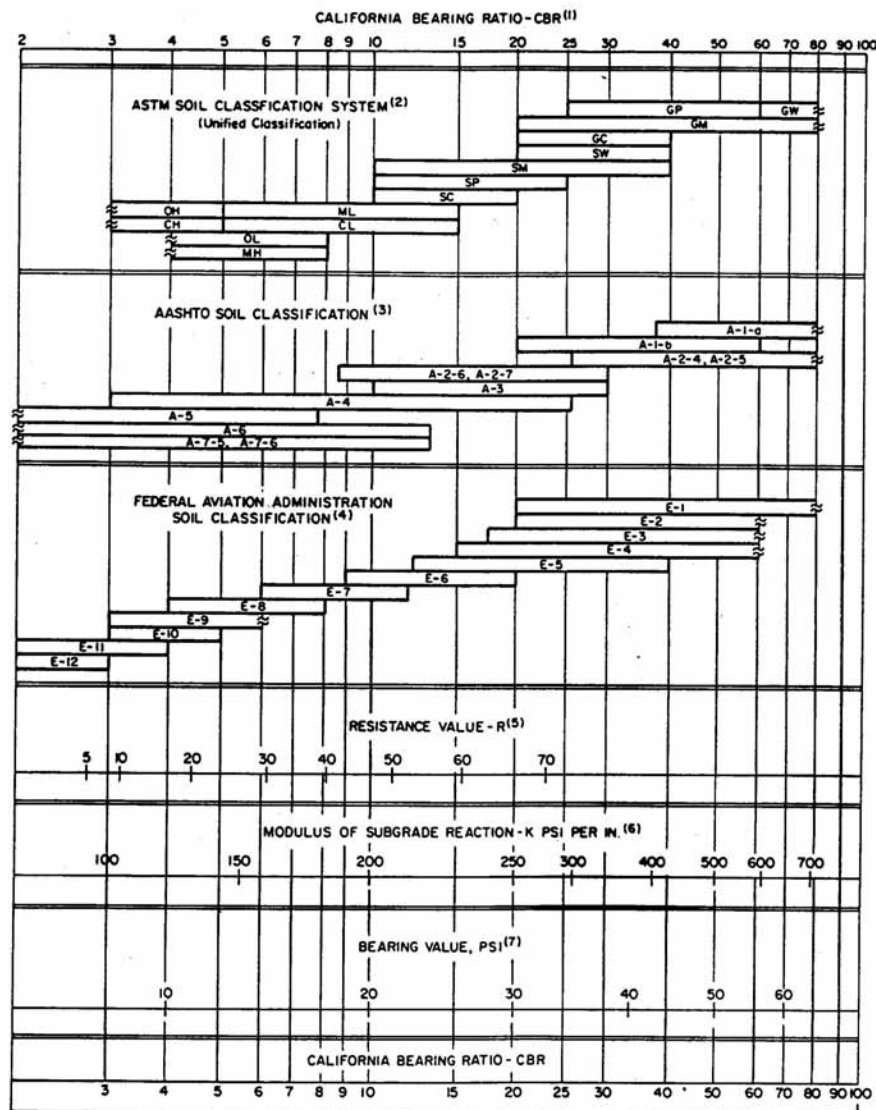


Figure 2-1 Soil descriptions.



(1) For the basic idea, see O. J. Porter, "Foundations for Flexible Pavements," Highway Research Board Proceedings of the Twenty-second Annual Meeting, 1942, Vol. 22, pages 100-136.

(2) ASTM Designation D2487.

(3) "Classification of Highway Subgrade Materials," Highway Research Board Proceedings of the Twenty-fifth Annual Meeting, 1945, Vol. 25, pages 276-282.

(4) Airport Paving, U.S. Department of Commerce, Federal Aviation Agency, May 1946, pages 11-16. Estimated using values given in FAA Design Manual for Airport Pavements (Formerly used FAA Classification; Unified Classification now used.)

(5) C. E. Warrens, "Correlation Between R Value and k Value," unpublished report, Portland Cement Association, Rocky Mountain-Northwest Region, October 1971 (best-fit correlation with correction for saturation).

(6) See T. A. Middlebrooks and G. E. Bartram, "Soil Tests for Design of Runway Pavements," Highway Research Board Proceedings of the Twenty-second Annual Meeting, 1942, Vol. 22, page 152.

(7) See item (6), page 154.

Fig. 16. Approximate interrelationships of soil classifications and bearing values

	Part. Size & Gradation			
	Approx. Size Range (mm.)		Approx. D_{10}	Approx. Range Unif. Coef., C_u
	D_{max}	D_{min}	(mm.)	
Granular Materials				
1. Uniform Materials				
a. Equal spheres (theoretical values)	—	—	—	1.0
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1
c. Clean, uniform SAND (fine or medium)	—	—	—	1.2 to 2.0
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0
2. Well-graded Materials				
a. Silty SAND	2.0	0.005	0.02	5 to 10
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6
c. Micaceous SAND	—	—	—	—
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300
Mixed Soils				
1. Sandy or silty CLAY	2.0	0.001	0.003	10 to 30
2. Skip-graded silty CLAY with stones or rk. frag.	250	0.001	—	—
3. Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000
Clay Soils				
1. CLAY (30 to 50% clay sizes)	0.05	0.5 μ	0.001	—
2. Colloidal CLAY (-0.002 mm. \leq 50%)	0.01	10 \AA	—	—
Organic Soils				
1. Organic SILT	—	—	—	—
2. Organic CLAY (30 to 50% clay sizes)	—	—	—	—

* Granular materials may reach e_{max} when dry or only slightly moist. Clays can reach e_{max} only when fully saturated.

† Granular materials reach minimum unit weight when at e_{max} and with hygroscopic moisture only. Clays reach minimum unit wet weight when fully saturated at e_{max} . The unit submerged weight of any saturated soil is the unit wet weight minus the unit weight of water.

Voids*					Unit Weight† (lb./cu. ft)					
Void Ratio			Porosity (%)		Dry Wt., γ_{dry}			Wet Wt., γ_{wet}		Sub. Wt., γ_{sub}
e_{max}	e_{cr}	e_{min}	n_{max}	n_{min}	Min.	100% Mod. AASHO	Max.	Min.	Max.	Min.
(loose)		(dense)	(loose)	(dense)	(loose)		(dense)	(loose)	(dense)	(loose)
0.92	—	0.35	47.6	26.0	—	—	—	—	—	—
0.80	0.75	0.50	44	33	92	—	110	93	131	57
1.0	0.80	0.40	50	29	83	115	118	84	136	52
1.1	—	0.40	52	29	80	—	118	81	136	51
0.90	—	0.30	47	23	87	122	127	88	142	54
0.95	0.70	0.20	49	17	85	132	138	86	148	53
1.2	—	0.40	55	29	76	—	120	77	138	48
0.85	—	0.14	46	12	89	—	146†	90	155†	56
1.8	—	0.25	64	20	60	130	135	100	147	38
1.0	—	0.20	50	17	84	—	140	115	151	53
0.70	—	0.13	41	11	100	140	148§	125	156§	62
2.4	—	0.50	71	33	50	105	112	94	133	31
12	—	0.60	92	37	13	90	106	71	128	8
3.0	—	0.55	75	35	40	—	110	87	131	25
4.4	—	0.70	81	41	30	—	100	81	125	18

† Applicable for very compact glacial till. Unusually high unit weight values for tills are sometimes due not only to an extremely compact condition but to unusually high specific gravity values.

§ Applicable for hardpan.

GENERAL NOTE: Tabulation is based on $G = 2.65$ for granular soil, $G = 2.7$ for clays, and $G = 2.6$ for organic soils.

DM 9.3	SHALLOW FOUNDATIONS	Page 1 of 1
	Presumptive Values of Allowable Bearing Pressures - Soils	October, 1995

Type of Bearing Material	Consistency In Place	Allowable Bearing Pressure kPa	
		Range	Recommended Value for Use
Well graded mixtures of fine and coarse-grained soil: glacial till, hardpan, boulder clay (GW-GC, GC, SC)	Very compact	766 to 1149	958
Gravel, gravel-sand mixtures, boulder gravel mixtures (SW, SP, SW, SP)	Very compact	575 to 958	670
	Medium to compact	383 to 670	479
	Loose	192 to 575	287
Coarse to medium sand, sand with little gravel (SW, SP)	Very compact	383 to 575	383
	Medium to compact	192 to 383	287
	Loose	96 to 192	144
Fine to medium sand, silty or clayey medium to coarse sand (SW, SM, SC)	Very compact	287 to 479	287
	Medium to compact	192 to 383	239
	Loose	96 to 192	144
Homogeneous inorganic clay, sandy or silty clay. See Note 2 (CL, CH)	Very stiff to hard	287 to 575	383
	Medium to stiff	96 to 287	192
	Soft	48 to 96	48
Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand. See Note 2	Very stiff to hard	192 to 383	287
	Medium to stiff	96 to 287	144
	Soft	48 to 96	48

Notes:

1. Compacted fill, placed with control of moisture, density, and lift thickness, has allowable bearing pressure of equivalent natural soil.
2. Allowable bearing pressure on compressible fine grained soils is generally limited by considerations of overall settlement of structure.
3. Allowable bearing pressure on organic soils or uncompacted fills is determined by investigation of individual case.

(Modified after Navfac DM 7.2)

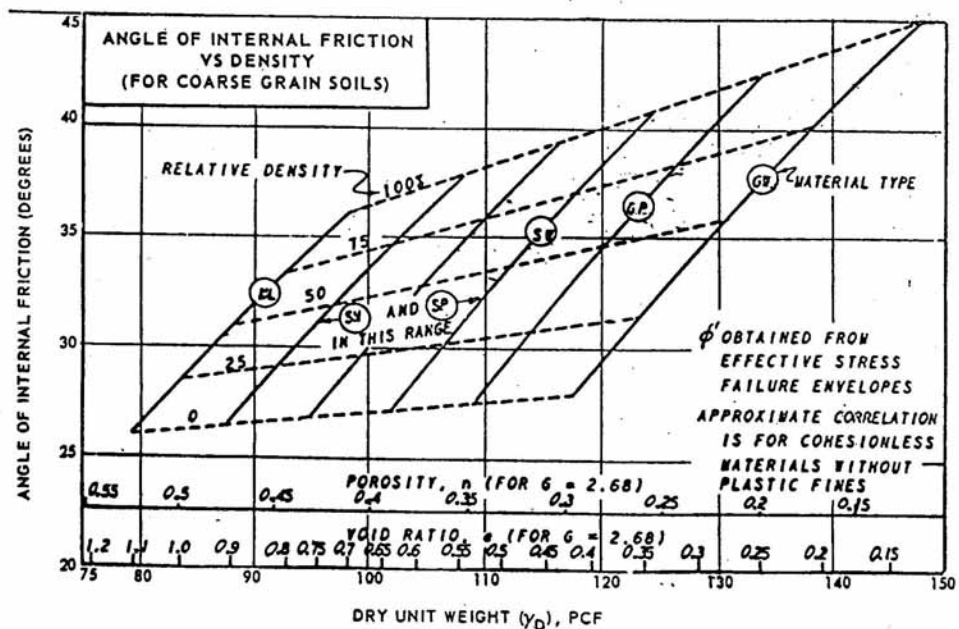
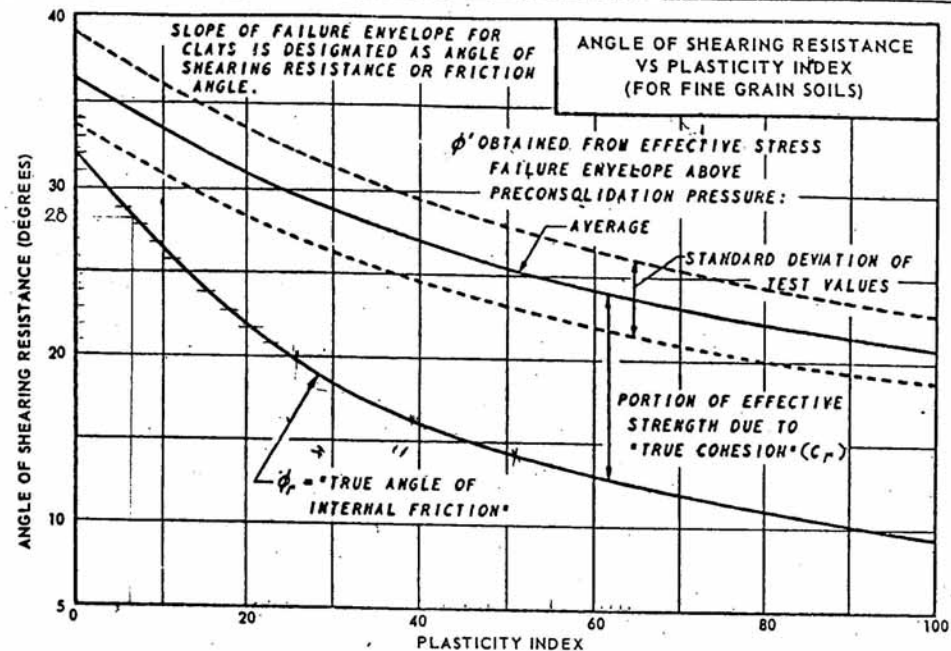


FIGURE 3-8
Correlations of Strength Characteristics

REFERENCES

AASHTO M145—The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

ASTM D 2487—Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ODOT SOIL AND ROCK CLASSIFICATION MANUAL
I:\Tech_Services\Geotechnical Services\Geotechnical Training\Drill Inspection Training

PCA Soil Primer (revised 1992)—by Portland Cement Association
Available through PCA at www.cement.org/bookstore

Soil Surveys—by State, then County and/or Area, compiled primarily by USDA Soil Conservation Service (now NRCS) and Forest Service (from data collected from 1954 to 1963); located in Geotech library

NRCS--Natural Resources Conservation Service
<http://soils.usda.gov/technical/classification/>

Dictionary of Geological Terms

NHI Course 13212 Manual—SOILS and FOUNDATIONS

NHI COURSE 132033 Manual--SOIL SLOPE AND EMBANKMENT DESIGN AND CONSTRUCTION

NAVFAC DM-7.1

Text: Basic Soils Engineering, 2nd Edition, by B. K. Hough

Presentation pdfs:
I:\Tech Services\Geotech Services\Ulrich\PDFs